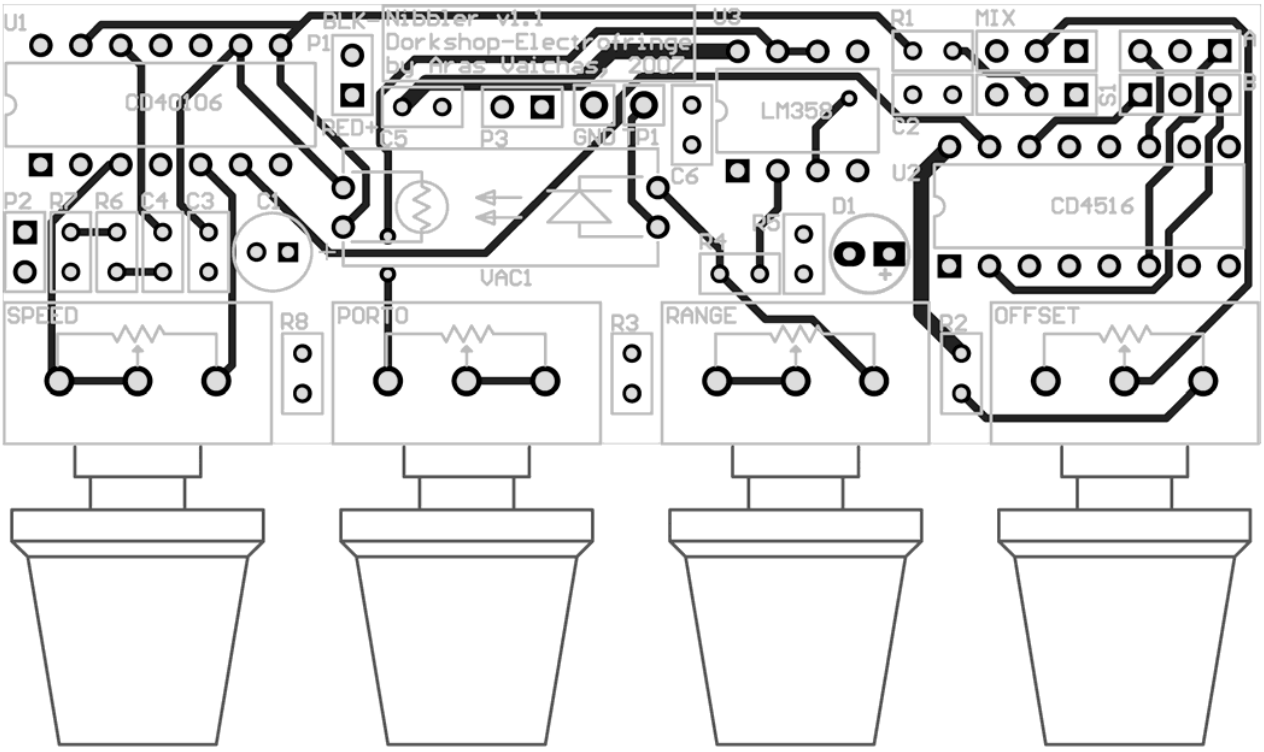
Dorkshop :: Workshop 1

Sound and Light

Project: Nibbler

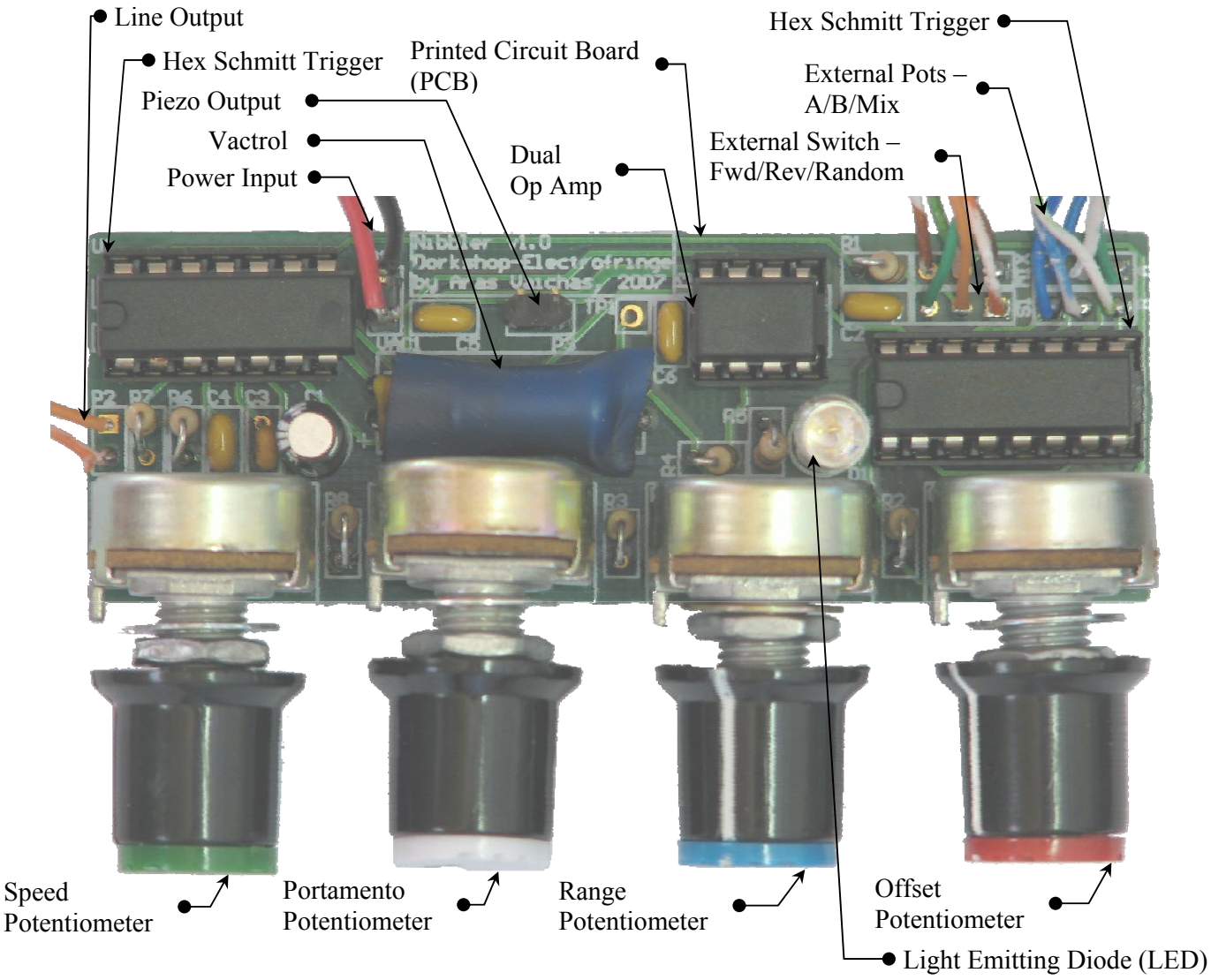
An audio pattern generator and noise-maker.



Dorkshop was designed by Aras Vaichas as an initiative by Dorkbot :: Sydney.
Dorkshop was taught by Aras Vaichas, Nick Wishart and Pia van Gelder.
Dorkshop was hosted and funded by the This Is Not Art festival :: Electrofringe, 2007

Nibbler :: External

The Nibbler is an example of a CMOS logic noise-maker circuit. It uses digital circuitry to create patterns of stepped tones, and analog circuitry to modify the sounds. The advantage of using this type of CMOS circuitry is that the device can be powered by a large voltage range, chips are easy to obtain, cheap to buy and hard to break.



Printed Circuit Board (PCB)

This was designed with a Schematic Capture and Layout software tool. The final PCB definition file was then sent to a PCB manufacturer to be made. The PCB is made in several process steps, most of which use traditional screen printing and photolithography techniques to print the photoresist and etch the copper. The colour of the board comes from the Solder Resist which is a screen printed layer that covers all the copper areas that do not require soldering.

Hex Schmitt Trigger - CD40106 (aka MC14106, or MM74C14)

This digital logic chip contains 6 inverters which turn a high signal into a low signal, and vice versa. Each input has a Schmitt Trigger filter which provides hysteresis and a certain amount of noise immunity. This chip is used as an oscillator for the pattern generator clock, the main oscillator for the sound generator and as a buffer between different parts of the circuit.

Presettable Up/Down Counter - CD4516

This digital logic chip is a 4-bit binary counter with a forward and reverse option. The four outputs from this chip generator the 16 unique digital patterns. The pattern generator clock oscillator in the CD40106 controls the speed of the counting. In computing, 8bits is called a Byte, while 4bits is called a Nibble - thus, the Nibbler was named,

External Controls – A, B and MIX

These three potentiometers (pots) take the four digital signals from the counter, which are all in parallel, and it mixes them all together into one analog control voltage (CV). This analog mixing creates a large range of possible patterns and sounds from the simple set of 16 patterns.

External Controls – Fwd/Rev/Random

This switch runs the counter forwards, backwards and randomly.

Vactrol

The vactrol converts a voltage into a resistance. Inside the vactrol is a light emitting diode (LED) which faces directly on to a light dependent resistor (LDR). As the LED glows brighter, so the resistance in the LDR decreases. This is a very simple way to control an oscillator with a CV. This particular vactrol is home made, but commercial ones are available.

Dual Op Amp – LM358

This chip has two operational amplifiers (Op Amps) in it, one of which is used to create the portamento and the other to control the vactrol.

Potentiometer – Speed

This controls the frequency of the pattern generator clock..

Potentiometer – Portamento

This adjusts the glide between note changes.

Potentiometer – Range

This controls the difference between the lower and upper range of the CV.

Potentiometer – Offset

This lifts the level of the CV.

Light Emitting Diode (LED)

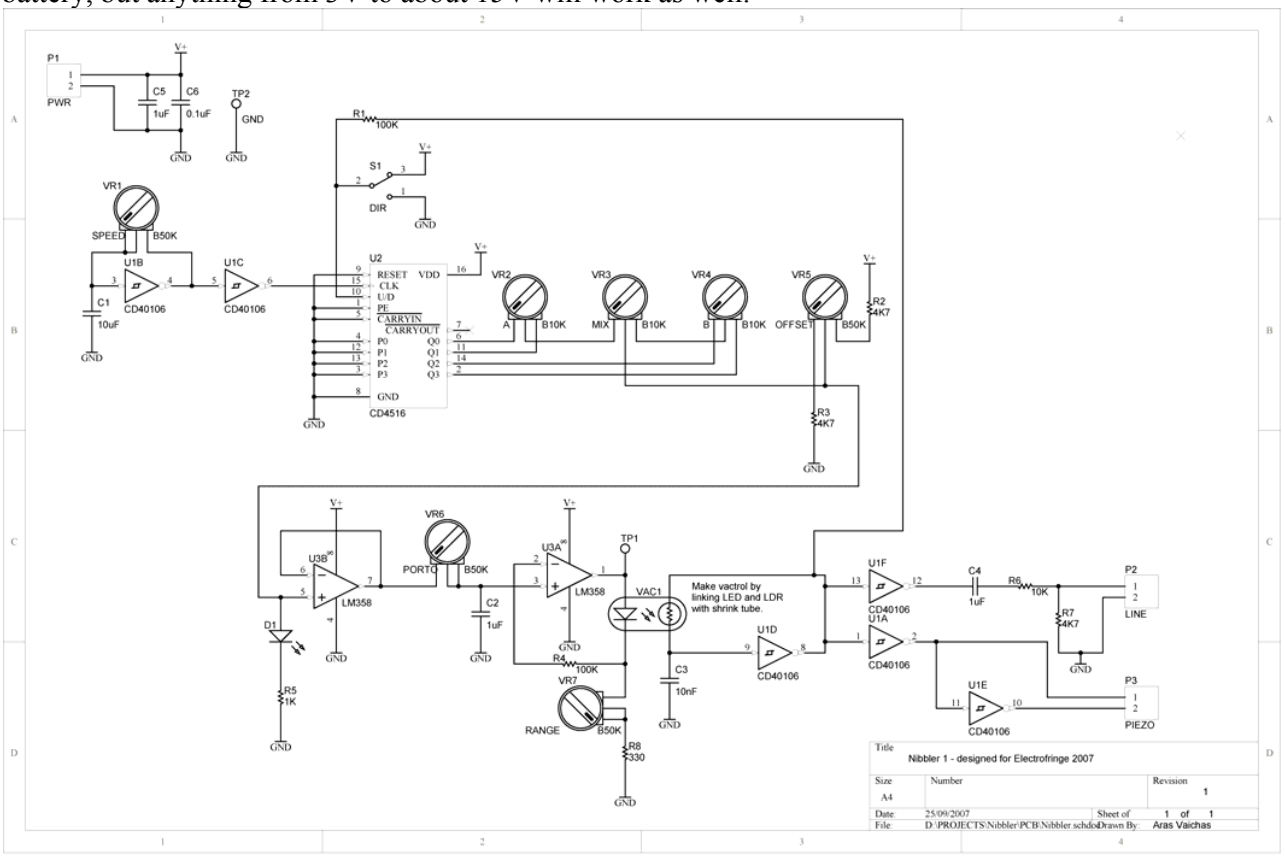
The light from this LED is directly proportional to the CV and gives a general indication of the rhythm and sound.

Nibbler :: Electrical

Analog audio design is often built with a number of stages that cascade into one another. There are many points in the circuit where the sound can be tweaked and modified and each stage adds a little bit extra to the final sound. Not to say that this is a fancy sound generator, but it is a reasonable starting point to learn about electronics.

Power Supply Input – P1

This is where the power supply enters the system. There are two capacitors here which help to smooth out any fluctuations from the power supply or the circuit itself. The power supply for this circuit will be a 9V battery, but anything from 3V to about 15V will work as well.



Speed Control and Counter Clock Oscillator – VR1, U1B, and U1C

This inverter U1B is one sub-section (one sixth) of the CD40106 chip and it is configured as an RC oscillator. When the output of U1B is high, it charges up the capacitor C1 via the pot VR1. When C1 is charged up, U1B will see a high level at its input and therefore it will invert this signal and make its output low. The low output on the inverter will discharge the C1 through VR1 until the input goes low. At this point the output will go high again and the cycle will repeat. This is a basic RC inverter oscillator. The frequency of this oscillation depends on the voltage of the power supply, the capacitor and the resistor. Since the power supply and the capacitor have fixed values, then the frequency is totally controlled by VR1, the speed control pot.

U1C is used as a buffer. This helps to keep the oscillator stable as it stops any other circuitry from "stealing" current from the capacitor and upsetting the oscillator.

Binary Counter – U2

On every rising edge of the clock, the counter will count by one increment.

The outputs, Q0-Q3, will count through a 4 bit binary sequence and then repeat. This gives 16 unique combinations.

When the output is a zero, the pin will allow current to flow in to it as it is effectively at the ground (negative) potential.

When the output is a one, the pin will supply a voltage at whatever the power supply is. This will be 9V for this circuit.

This counter has options to pre-set the outputs and accept carry-in from other counters. These options have been ignored and are disabled by setting the pins low. The only option that is used, is the Up/Down option.

CLK	Q3	Q2	Q1	Q0
↑	0	0	0	0
↑	0	0	0	1
↑	0	0	1	0
↑	0	0	1	1
↑	0	1	0	0
↑	0	1	0	1
↑	0	1	1	0
↑	0	1	1	1
↑	1	0	0	0
↑	1	0	0	1
↑	1	0	1	0
↑	1	0	1	1
↑	1	1	0	0
↑	1	1	0	1
↑	1	1	1	0
↑	1	1	1	1

A, B, and Mix Potentiometers – VR2, VR3, VR4

This is where the Control Voltage (CV) is created. These pots work as voltage dividers between the outputs of the counter. The A pot mixes the Q0 and Q1 outputs, the B pot mixes the Q2 and Q3 outputs, and finally the MIX pot mixes the A and B together. This is very similar to an audio mixer which only has balance controls for each input.

For example, if Q0 was high and Q1 was low, then VR2 would be able to provide a voltage level somewhere between the power supply voltage and zero volts. The same goes for VR4. VR3 provides a mix between VR2 and VR4.

For example, if a person only wanted to hear what happens when Q3 goes high, they would turn the VR4 pot towards the Q3 side and turn VR3 towards the B pot. Thus, the CV will go low for 8 clock cycles, and then go high for 8 clock cycles.

Offset Potentiometer – VR5

Another voltage divider, this pot mixes in some of the power supply voltage to lift or lower the voltage level coming out of the MIX pot, VR3. The two resistors, R2 and R3, on either side limit the amount of voltage that VR5 can apply to the CV.

$$V\max = \frac{50K + 4K7}{50K + 4K7 + 4K7} V = 0.92V$$

$$V\min = \frac{4K7}{50K + 4K7 + 4K7} V = 0.08V$$

Light Emitting Diode – D1

This LED monitors the CV line. The LED will only illuminate when the CV level is greater than the forward voltage (Vf) of the LED, at this point it conduct and begin to drain some of the current from the CV, which in turn has an affect on the final sound output. Therefore the type and colour of the LED used here can make a big difference to the sound and behaviour of this circuit. This is generally a bad thing in circuit design, but the aim of this circuit is to break a few rules and to produce a circuit with character. R5 limits the current through the LED, otherwise it would be a short circuit when the LED conducts.

Portamento Control – U3B, VR6, C2

The op-amp, U3B is one half of the LM358 dual operational amplifier. This op-amp is configured as a voltage follower where the output is always equal to the input. This provides isolation between the sensitive CV section and the following sections of the circuit.

The pot VR6 and capacitor C2 create a low pass filter so that sudden changes in the CV will be rounded off and smoothed. This effectively creates a glide effect. The amount of smoothing is proportional to the product of C2 and VR3, and since C2 is fixed, the glide is controlled totally by the PORTO pot VR3.

Vactrol Control – U3A. VAC1, VR7

This circuit drives the LED inside the vactrol VAC1. U3A is configured as a Voltage Controlled Current Source (VCCS), so that the current on the output is proportional to the voltage on the input. This is needed because the amount of light that the LED produces is equal to the amount of current flowing through the LED. The LED will only start to conduct, and produce light, when the input voltage is above the forward voltage (Vf) of the LED. Since LEDs vary, we need to compensate for this. We provide a feedback loop via R4 which allows the op-amp to sense the current flowing through the LED. VR7 limits the maximum current allowed to flow through the LED, and therefore sets the maximum brightness that the LED can reach.

Example: Let's assume that VR7 is set to zero ohms. Using Ohms Law, the voltage sensed by the op-amp is equal to the current flowing through the LED multiplied by the resistance of (VR7 + R8). Note that no current flows through R4! The job of the op-amp is to make its negative input pin equal to its positive input pin. Therefore, if the input to the op-amp was 5V the voltage between the LED and VR7 *has* to be the same, 5V. The current flowing through the LED and VR7 would be: 5V / 330ohms = 15mA.

This is about half of what the LED needs for full brightness. If our power supply was 9V, then 5V would be about half way for half brightness. This seems reasonable.

If VR7 was set to its maximum at 50K ohms, and the input was 5V, then the current flowing would be: 5V/ (50K + 330)ohms = 0.01mA. A very small amount, but enough for the LDR to detect.

Main Oscillator – VAC1, U1D, C3

The end of the vactrol with the LDR forms an RC oscillator with the inverter U1D and capacitor C3. As the LED in the vactrol glows brighter, the resistance of the LDR will decrease, the capacitor C3 will charge up faster and therefore the frequency of the main oscillator will go up.

It can now be seen that the vactrol and the main oscillator form what is known as a Voltage Controlled Oscillator (VCO). A common part of a synthesizer.

Counter Direction Switch – S1, R1

The switch S1 is a Single Pole Double Throw (SPDT) switch with an off position, ON-OFF-ON. R1 provides a voltage that comes straight from the main oscillator. When S1 is set to the top position, it provides full power supply voltage to the direction pin on U2. Since the current from the full power supply is much stronger than the main oscillator flowing through R1, a 100K resistor, the direction of the counter will be stable and it will count upwards. The same goes when the switch is in the down position, R1 can not influence this signal and it has no effect. When the S1 is in the OFF position it will not be connected to anything else but R1 and the signal coming from R1 will determine the count direction. The counter only takes notice of the direction signal when the counter clock goes high so the direction will be randomly selected since the main oscillator could be either high or low when the counter clock goes high.

Line Out – U1F, C4, R6, R7, P2

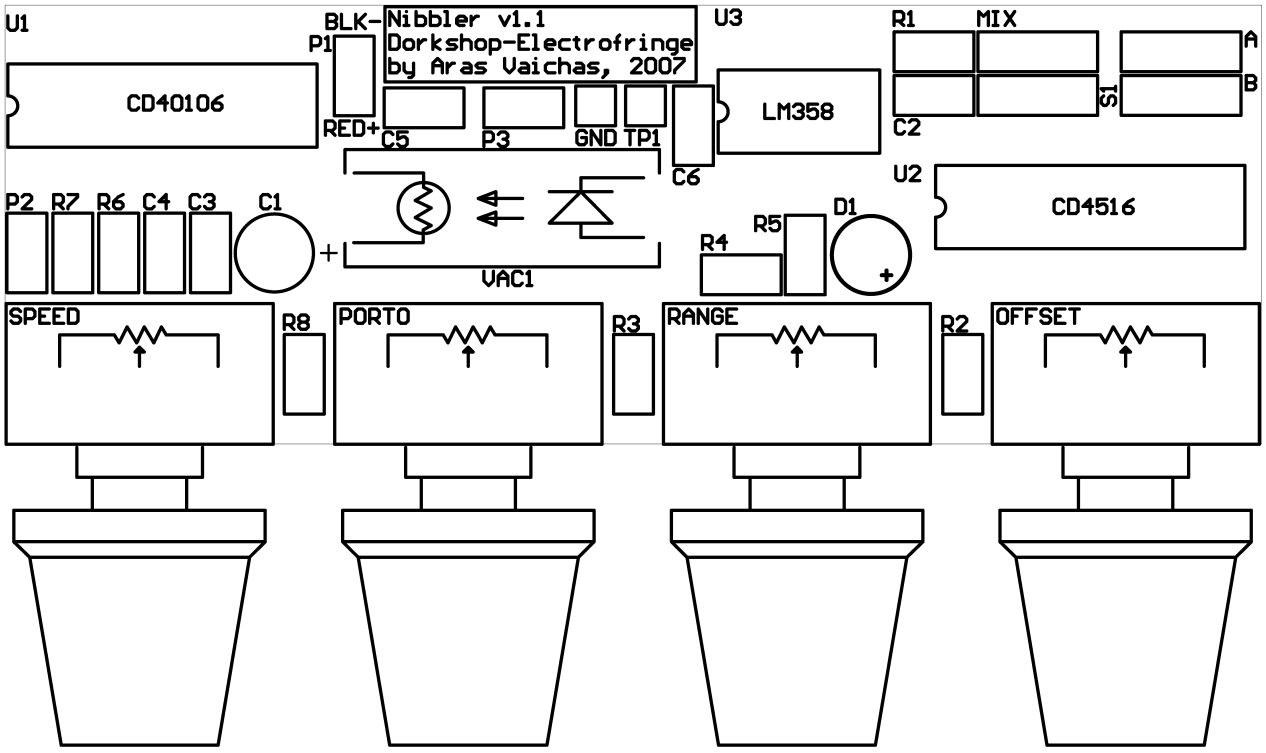
The line out signal is first buffered by U1F. Capacitor C4 removes the DC offset from the signal and, with R6 and R7, creates a high-pass filter with a very low cut-off frequency, less than 10Hz. R6 and R7

create a voltage divider which brings the final output level closer to what is expected by normal mixers and amplifiers. The level is still very high at this point and further volume level control is recommended.

Piezo Out – U1A, U1E, P3

This was an experiment in using an inverter as a Bridge Tied Load (BTL) output. U1A and U1E provide two signals that are the inverse of each other. i.e. When one is high, the other will be low and vice versa. This is a method for driving a piezo or a speaker to get extra power and volume. Not recommended for 8ohm speakers as the inverters can not provide any real current.

Nibbler :: Assembly



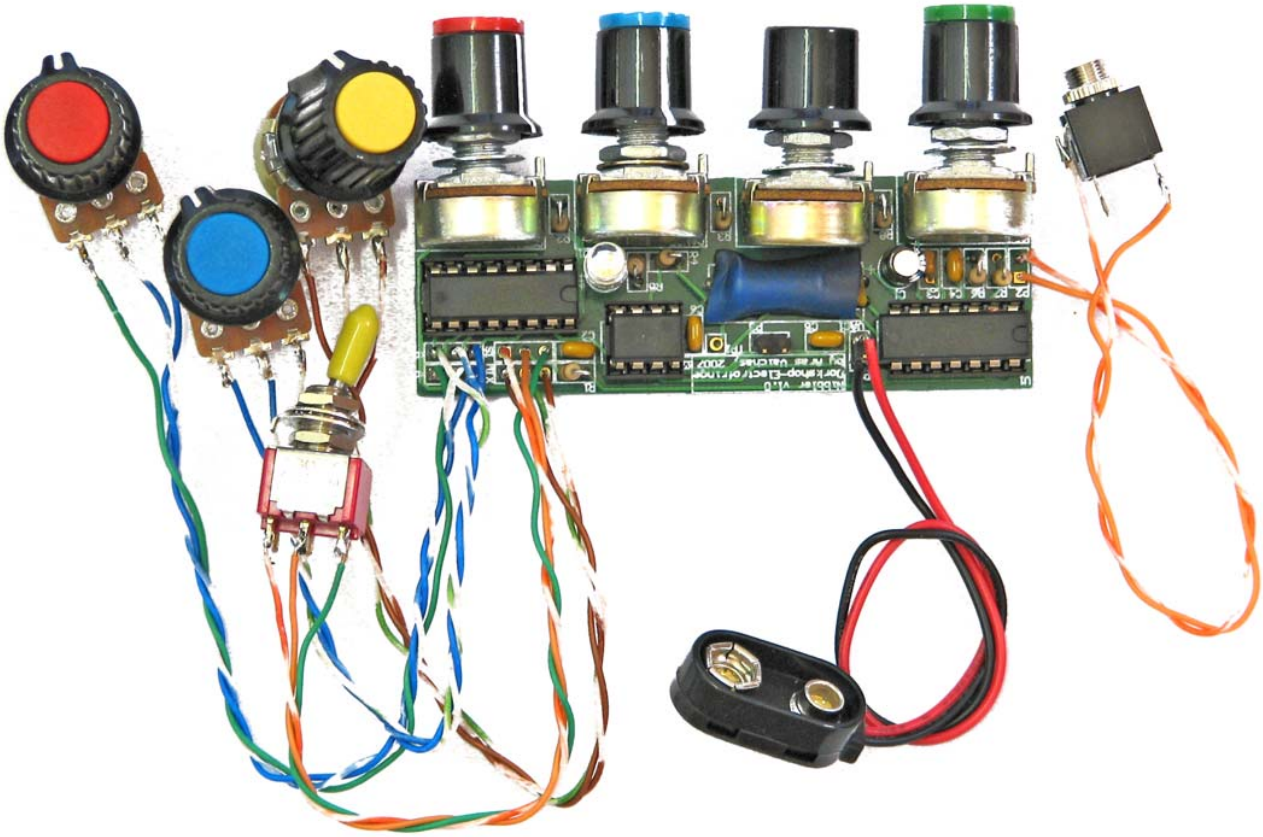
Parts List:

R1, R4, 100K resistor, ¼W, marking: BROWN-BLACK-BLACK-ORANGE-BROWN
R2, R3, R7 – 4K7 resistor, ¼W, YELLOW-PURPLE-BLACK-BROWN-BROWN
R5, 1K resistor, ¼W, BROWN-BLACK-BLACK-BROWN-BROWN
R6, 10K resistor, ¼W, BROWN-BLACK-BLACK-RED-BROWN
R8, 330R resistor, ¼W, ORANGE-ORANGE-BLACK-BLACK-BROWN
C1 – 10µF capacitor, electrolytic, polarised, long lead goes in the square + hole.
C2, C4, C5 – 1µF capacitor, monolithic, marking: 105
C3 – 10nF capacitor, monolithic, marking 103
C6 – 0.1µF capacitor, monolithic, marking: 104
D1 – LED, blue, polarised, long leg goes in the square + hole.
P1 – 9V battery clip, polarised, red wire goes in the bottom hole, black wire goes in the top hole.
P2, P3 – 2x1 Single Inline Pin (SIP) breakaway headers
S1, A, B, MIX – 3 pieces of single core wire, 10cm long, attach to 10K pots, marking: B10K.
U1, U2, U3 – IC sockets
VAC1 – Vactrol, see assembly hints. Polarised, long leg goes into the bottom right hole.
SPEED, PORTO, RANGE, OFFSET – 50K potentiometers, marking: B50K

Assembly Hints

1. DOUBLE CHECK all values before you solder them in, as it is difficult to remove them afterwards. If in doubt, use the multimeter to check the resistors or ask a supervisor to check your work.

2. Follow the parts list for the best order to assemble.
3. If you intend to put the Nibbler into a box, you might want to put the LED on some leads instead. So solder two pieces of hookup wire where the LED should go. Try and use red wire for the + lead.
4. Twist each triplet of solid core wires together so they don't move around and break. Solid core wire can easily snap inside if it is bent too many times. Then solder the 10K potentiometers on end of each pair of wires making sure the middle pin on the pot goes to the middle hole on the pad. It is easiest to tin the pins on the pots first, tin the solid core wire and then remelt them together.
5. Use Bluetack to hold the sockets in place while you solder them.
6. To make the vactrol:
    a. Take a green LED and an LDR
    b. cut exactly 2cm of the small heatshrink tubing
    c. place the LED and LDR inside the tubing so that they face each other.
    d. make sure that both sets of leads are aligned with each other and sit flat. do not bend them!
    e. heat the tubing with a flame, hot air gun, or side of soldering iron so that it shrinks, don't let the two parts move away from each other. While it is still warm, pinch the two ends shut so no light can get inside.
    f. cut a 2cm piece of the large heatshrink and shrink it over the top of the first one, crimp each end the same way.
    g. Cleanly fold the two sets of legs so that the longest leg is in the bottom right corner and so it fits into the VAC1 holes.
7. When the circuit is finished, get it checked by a supervisor.
8. Use the IC pin straightening tool to straighten the pins out on the ICs, then carefully plug them in.



Nibbler :: Links

Operational Amplifiers

The best selection is from Texas Instruments:
A Single-Supply Op-Amp Circuit Collection - focus.ti.com/lit/an/sloa058/sloa058.pdf
Filter Design in Thirty Seconds - focus.ti.com/lit/an/sloa093/sloa093.pdf
Handbook of Operational Amplifier Applications - focus.ti.com/lit/an/sboa092a/sboa092a.pdf
Op Amps For Everyone – 464 pages! - http://focus.ti.com/lit/an/slod006b/slod006b.pdf

Noise and circuit bending related stuff

Music from Outer Space – Wacky Sound Generator and more, www.musicfromouterspace.com

Cliplead – inspiration for the Nibbler, www.cliplead.com

Synthmonger – inspiration for the Nibbler, www.myspace.com/synthmonger, www.youtube.com/user/synthmonger

Seb's Synth DIY Pages – lots of stuff, burnit.co.uk/sdiy/

YouTube – keyword search for "noise circuit bend", much to explore, www.youtube.com

Miscellaneous Recommend Suppliers

Jaycar and Dick Smith – Good general supply www.jaycar.com.au, www.dicksmith.com.au

Electus Distribution – this is the wholesaler for Jaycar, exactly the same stock but about 30% cheaper. $100 minimum purchase, or surcharge applies. Good place to kick-start your electronics laboratory www.electusdistribution.com.au

Futurlec – extremely cheap (price and quality) parts, cheap shipping, Australian based, shipped from Thailand. Can take up to 4 weeks for delivery if parts are on backorder. www.futurlec.com

EBay – just search for your parts and you will probably find them. Hong Kong and Chinese retailers have proven to be cheap, fast and good. www.ebay.com

SURE Electronics - Hong Kong based, sells on EBay, very easy to deal with, reliable and fast to ship. stores.ebay.com/Sure-Electronics

Electronics Goldmine – loads of crazy cheap stuff. USD$50 minimum International order policy. www.goldmine-elec.com

Digikey – Digikey have a huge stock and give discounts for bulk, excellent search engine, good for "discovering" new parts. www.digikey.com